Slimhole vs. Microhole: Future of E&P

2005 SPE ATCE
Slimhole Drilling Session

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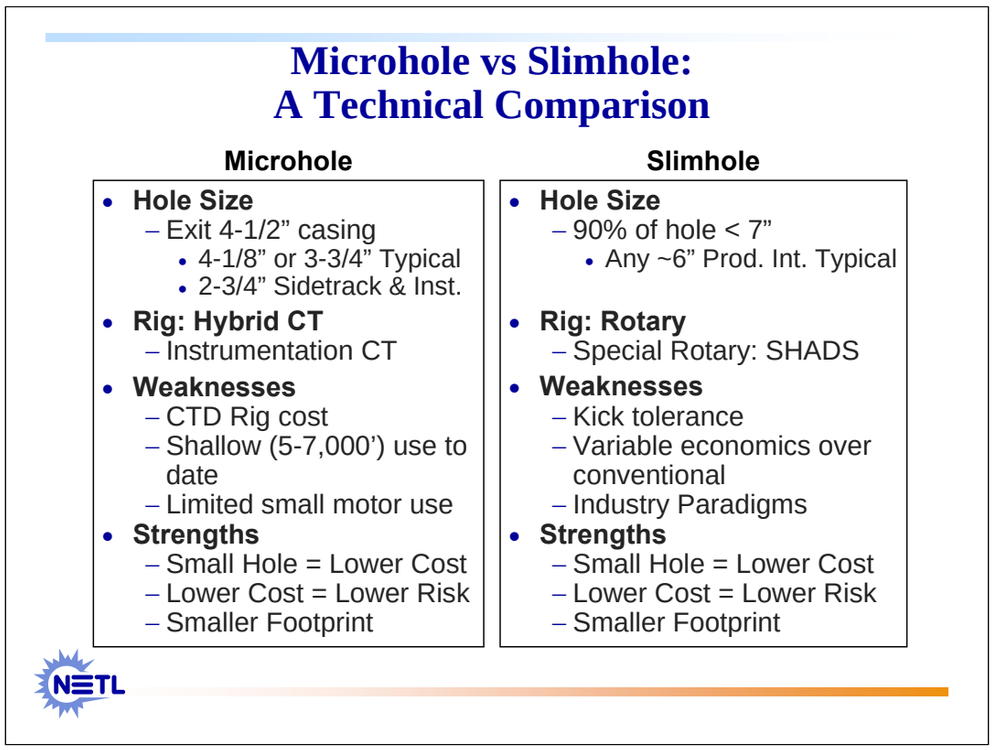
National Energy Technology Laboratory-SCNGO

Office of Fossil Energy

This presentation was given as the Keynote to the SPE/ATCE 2005 Slimhole Drilling Session. Text covering the initial Keynote address has been expanded in this electronic version to provide more detailed information than was possible to give during the original time-limited introduction. The author can be contacted at roy.long@netl.doe.gov should readers have further questions.



Microhole builds on many of the Slimhole concepts and the technologies historically proven to be sound and successful in the proper applications. Both Slimhole and Microhole focus on technologies that attempt to decrease field development cost by decreasing the hole size, and hence cost of all associated construction materials and time, required for exploration development. From a technical perspective, Microhole might be thought of as taking off where Slimhole ends. For example, Slimhole originally focused on tools for 6” diameter holes, typically setting 4-1/2” casing. Microhole pushes that envelope by focusing on tools for boreholes 4-3/4” and less in diameter, and especially those tools and technologies involved in drillling out of existing boreholes with 4-1/2” casing (and smaller) set in the production interval.

Industry is fairly familiar with Slimhole technologies; and, Microhole is often misinterpreted as another Slimhole approach. However, Slimhole primarily focuses on smaller downhole tools while still utilizing rotary rig technologies. In contrast, Microhole takes what initially might be considered a counterintuitive approach by utilizing coiled tubing drilling, recognized to be associated with a higher daily cost. The reason this is done is because only coiled tubing rigs can be utilized with high penetration rate drilling assemblies to result in a “system” capable of achieving new levels of economic access from existing wellbore infrastructure. This “system” also allows economic access to the extensive shallow gas resource not previously considered economic. This is the essence of what is referred to as the “systems approach” to lower cost access. The term Microhole is currently being utilized by DOE to describe a focus on technologies to further develop the many mature complex/compartmentalized reservoirs known to exist within the domestic U.S. resource base. The key to developing resources in mature complex reservoirs is to recognize that a combination of interrelated technology systems working together toward this common objective will be required. DOE’s Microhole Technologies (MHT) Program employs a systems approach in that it considers the larger picture to complex reservoir development and takes into account how factors such as technology, research, risk, and the business environment contribute to the overall success or failure of resource development. The systems solutions to resource development must address the following “resource development drivers”:

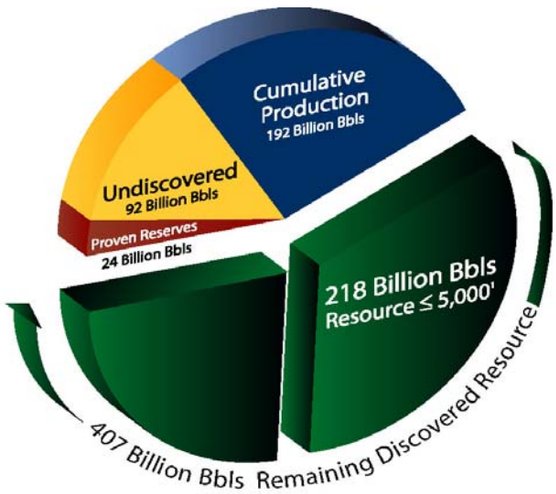
• Reduced reservoir access cost (drilling, including mobilization) to allow more holes to be drilled to penetrate reservoir seals and/or within-zone barriers.

• Cost-effective high-resolution imaging to locate bypassed oil and reservoir seals, and allow better management of sweep efficiency in enhanced oil recovery processes.

• Increased drilling efficiency (expressed in more completed wells per week) that will require high penetration rate drilling assemblies.

• Smaller drilling footprints to minimize disruption of landowner activities, especially considering the larger number of wells required for access.

MHT Program "Singular Goal": Greater Mature Domestic Oil Resource Recovery



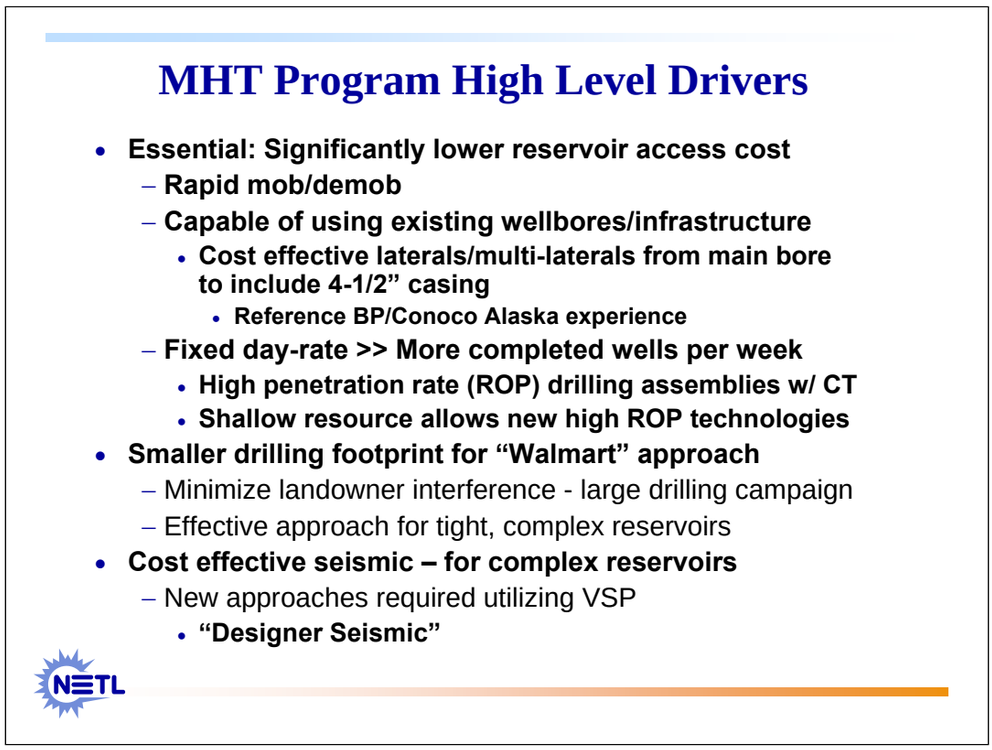
- **407 Billion Barrels not economically recoverable with current technology**
- **218 Billion Barrels from shallow development alone**
  - **Conservative recovery estimate = 10 years of OPEC imports offset**

Source: EIA, 1997; USGS, 1995; IPAA, 1998; Intek, Inc., 1998

DOE's Microhole Technologies Program has its roots in NETL's Oil Program as a methodology to recover additional reserves from the known oil resource base. At the initiation of the Program, an estimated 407 billion barrels of onshore discovered oil in the U.S. was non-recoverable with existing drilling and production technologies. Of that total, 218 billion barrels could be found at the relatively shallow depths of 5,000 feet or less. Even at today's high oil prices, industry-sponsored research remains on the decline, and operators tend to use familiar technologies rather than risk failure with advanced technology. To bridge this technology gap,

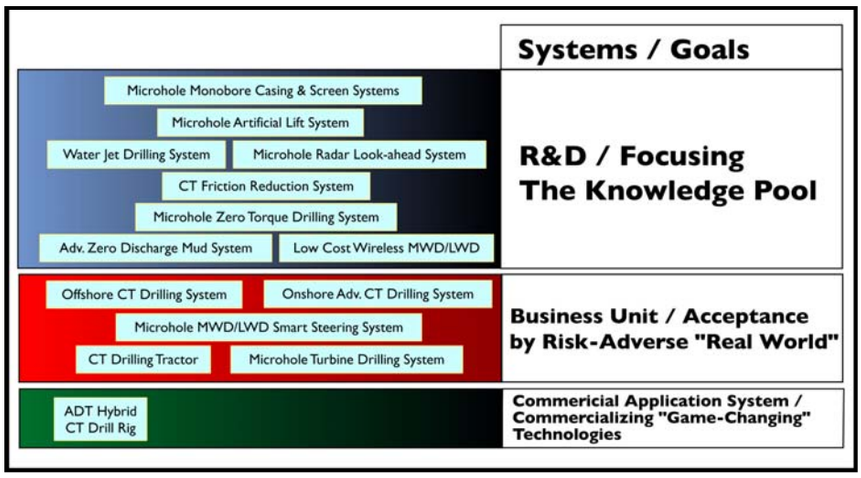
DOE partnered with industry to develop and demonstrate new technologies to access additional recovery of domestic petroleum resources once thought to be uneconomic.

The reduced cost of shallow access and monitoring has been well received by the independent producer industry for further development of mature fields. As noted in this slide the anticipated resource to develop is significant. If only ten percent of the shallow remaining resource can be developed, it will be equivalent to eliminating 10 years of imported OPEC oil. The difficulty is that the resource is not located in a few large reservoirs, but rather distributed over many reservoirs. Hence the best avenue for development is to enable all domestic producers owning this resource by encouraging industry to build the tools to develop it economically.



As noted previously, the business focus of the MHT Program requires new technologies to specifically address increased efficiency, and thus reduce total cost/risk. Coiled tubing drilling, despite its high day rate, is combined with high penetration rate drilling assemblies in shallow drilling environments to achieve field wide economies not achievable by any other approach. When rapid low cost access is coupled with Vertical Seismic Profiling (VSP) new data acquisition capabilities can be realized. Better understanding of both static and dynamic conditions and processes occurring in the reservoir are essential to improved recovery. This results in a paradigm shift in information acquisition and processing (essentially a significantly greater focus on new levels of high resolution imaging in real time and yet at lower "unit" cost).

Microhole Technologies System Model:
Shallow, Uneconomic Oil and Gas Resource Development



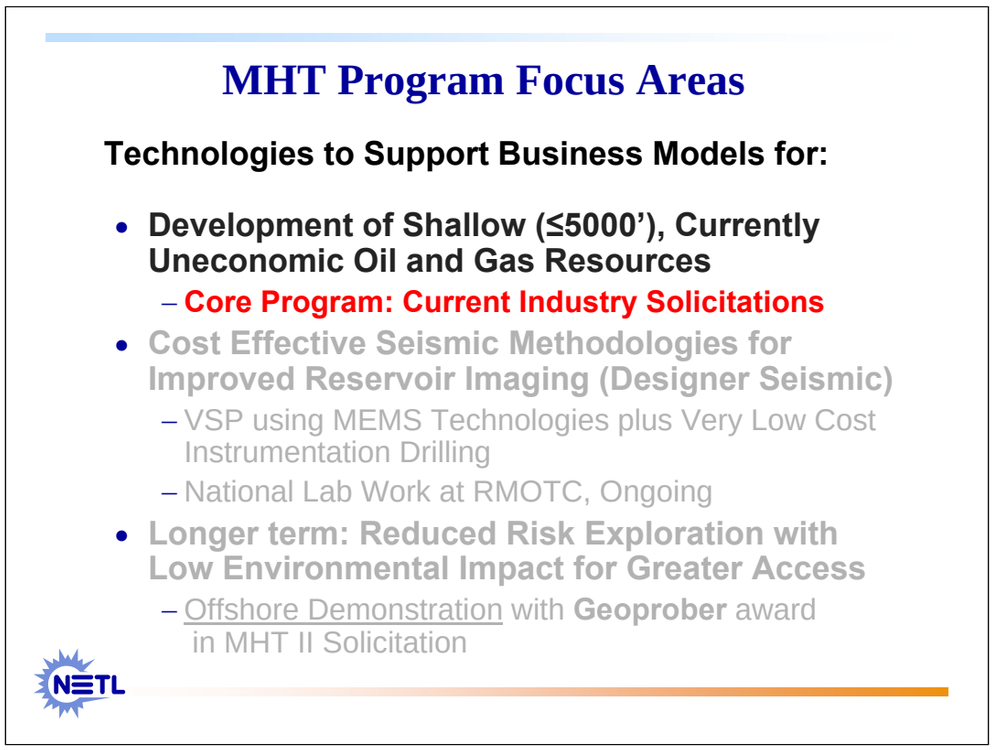
Systems Engineering: "~ the art and science of creating optimal system solutions to complex issues and problems" - Prof. Derek Hitchins

Diagram and quotes from Prof. Hitchens Website at http://www.hitchins.net

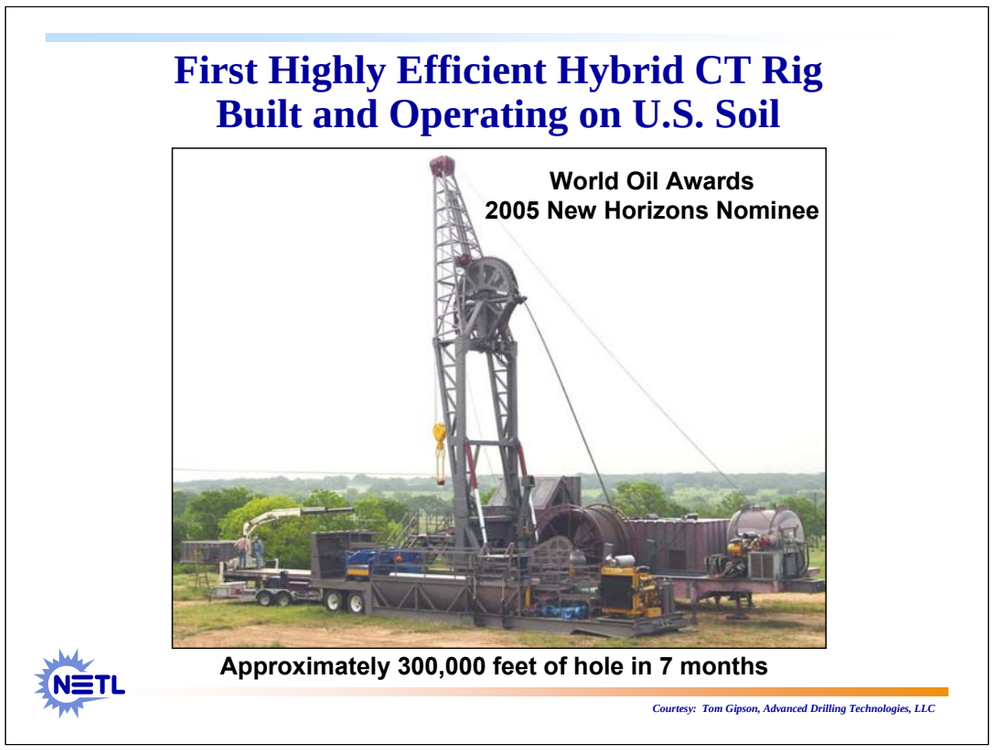
As a variation to the "stage-gate" process, this slide organizes the existing MHT Program projects within three recognized systems (with goals of each) that contain the projects. The MHT Program is relatively short focused (3-5 years). Longer term projects identified as still being in development stages must still have a rather focused functional goal essential to increasing small hole coiled tubing drilling efficiencies and reducing environmental impact.

The Business Unit system requires those more mature projects to provide incentive for rapid penetration into existing markets. These projects typically build on existing technologies and usually have significant market pull for expanded resource development.

The Commercial Application system represents those projects involved in field demonstrations for immediate application of these technologies. Most notably is Advanced Drilling Technologies' hybrid coiled tubing drilling rig. This system is similar to the shallow gas CT units used in Canada; however, it specifically addresses low environmental impact as an enabling capability to enhance high density drilling operations on existing farm land. Performance achievements and awards recognition resulting from the use of this system will be discussed in a subsequent slide (#7).



Projects from recent DOE solicitations directly support access technologies for developing the shallow oil and gas resource. This forms the core of the program for reducing access cost. It encompasses and supports the field demonstration program focused to demonstrate the economics and potential of the approach to utilize Coiled Tubing drilling rigs to drill shallow, small diameter wellbores.



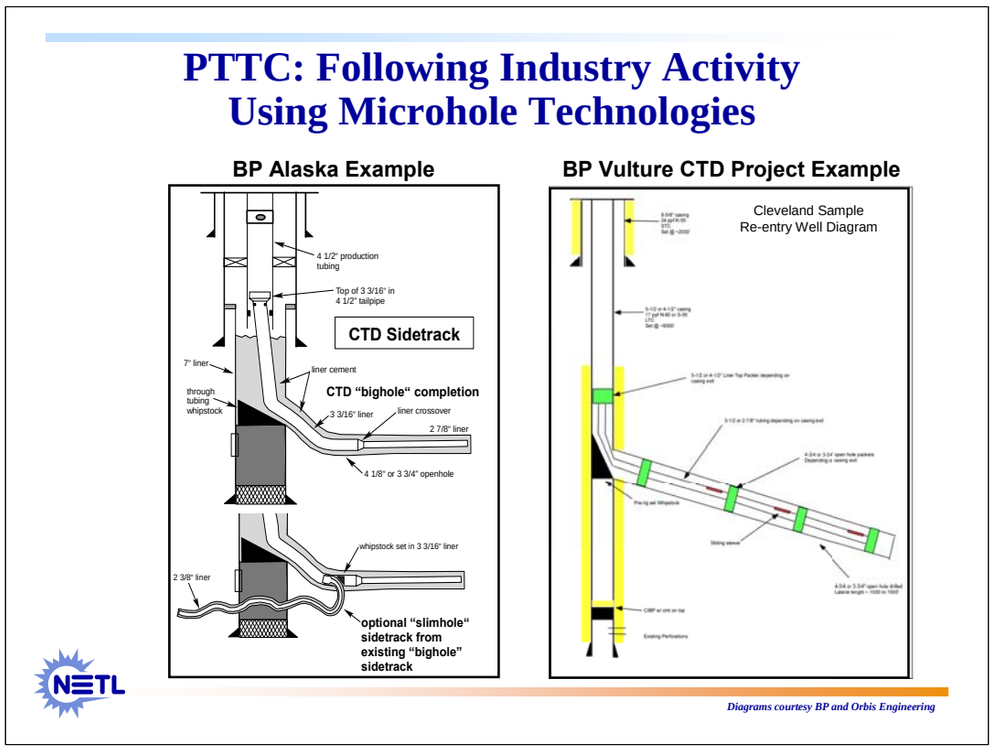
As noted previously, the hybrid coiled tubing drilling rig in DOE's demonstration program has specifically been built for rapid mob/de-mob and efficient small borehole drilling operations. The rig is contained in four highway legal trailer loads. The rig can move into many locations without the need for grading or other location preparation. The latest statistic for this rig is that it recently drilled and completed a 2,800', 4-3/4" hole, cemented 2-7/8" casing, and moved out in 19 hours. While rigs/drilling systems in Canada have achieve shorter move-in/move-out times, this is one of the fastest in what was previously considered the harder drilling environments in the lower 48. Not only was the rig nominated for the 2005 World Oil New Horizons Award, the State of Colorado nominated the operator, Rosewood Resources, as operator of the year for 2005 because of the rigs low environmental impact and drilling efficiency. From an economic perspective the rig is enabling development of shallow tight gas wells less than 100 MCFD. As directional/horizontal drilling capabilities are made more effective, this initial production rate for wells of this type are expected to increase significantly. In addition, the rig is currently being evaluated for use in Coalbed Methane drilling and is expected to be an economic means to achieve greater CO2 injection into the reservoir over a wider area. Being able to cost effectively drill across permeability barriers and provide new low cost injection points is expected to be an invaluable capability in future CO2 EOR programs.

MHT Awards

(See: www.microtech.thepttc.org)

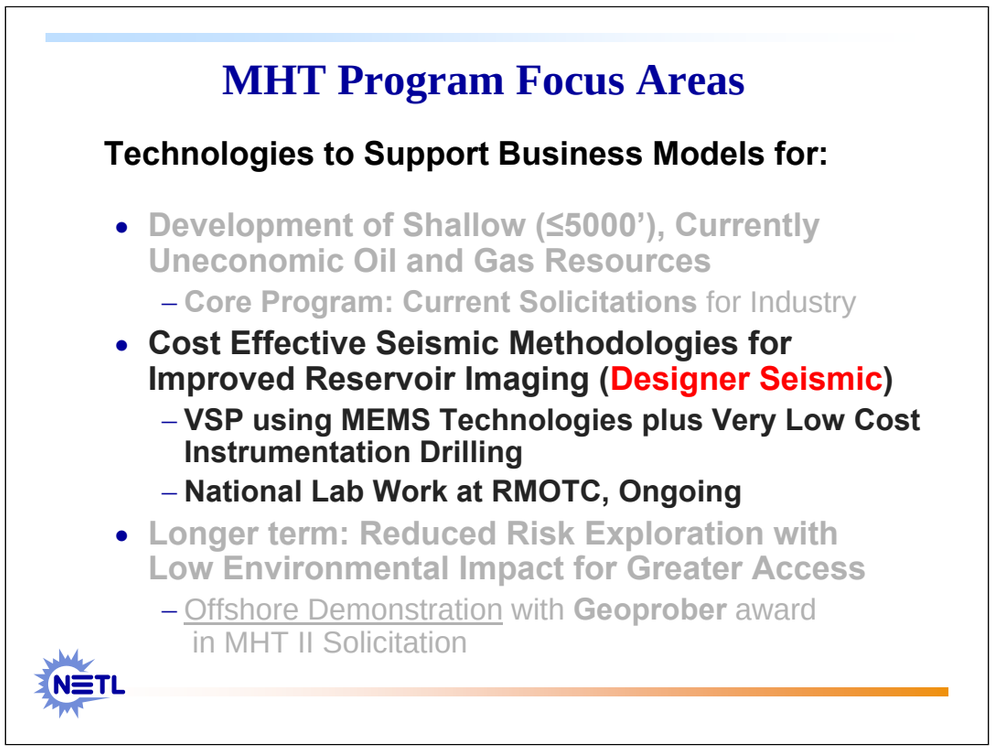
Applicant	Technology
Stolar Research Corp.	Radar Guidance System
Gas Production Specialties	Artificial Lift System
Baker Hughes Inteq	Smart Steering System (LWD)
Bandera Petroleum	Zero Discharge Mud System
Schlumberger	Hybrid Coiled Tubing Drlg. Rig
Western Well Tool	Microhole Drilling Tractor
Geoprober	Deepwater Demo
GTI	Onshore Demo
GTI	Zero Torque Drill Motor
Tempress	Waterjet Drilling System
CTES	CT Vibrator
Technology Int.	Turbodrill
Ultima Labs	MWD/LWD Comm. Sub
Baker Hughes Inteq	Comm. Sub
Confluent Filtration	Monobore
Confluent Filtration	Expanding Screen

A summary of the MHT Program projects can be found on the Petroleum Technology Transfer's website, as noted on this slide, where the reader can also find more information on both the projects and the MHT Integration meetings organized to follow the technologies as they develop. The meetings are typically held quarterly the Wednesday before the Thursday Drilling Engineering Association meetings (www.dea.main.com).

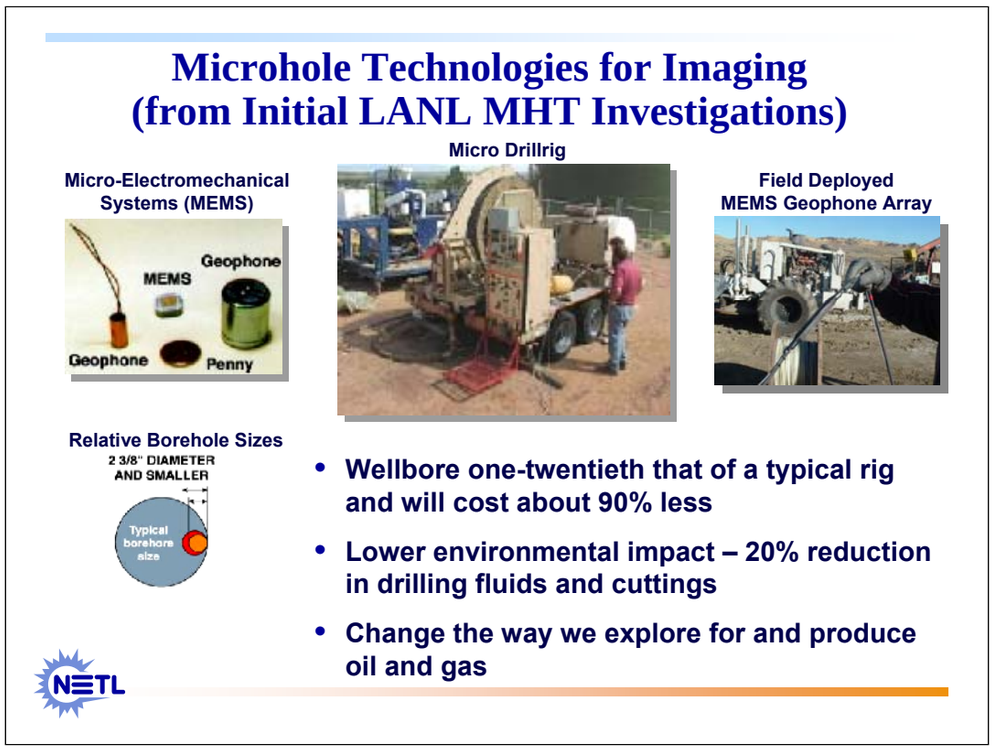


The PTTC Microhole Integration meetings follow not only DOE sponsored applications of microhole technologies but also those currently used by industry. Both BP and ConocoPhillips have made presentations of their Alaskan operations. BP is also evaluating application of the technologies for shallow gas resource development using existing infrastructure. Results of that test are expected to be presented at the March 22, 2006 meeting.

The two companies announced at the 2005 SPE/ICOTA Conference that they had just completed their 100th
2-3/4" sidetrack from an existing 3-1/2" multilateral. The response they received from the audience following this announcement was similar to the "dear in front of headlights" look received from the announcement during this Keynote address. "Why would they do that?", was the obvious question. They do that because, having good seismic, they can cost effectively drill out of existing boreholes (using existing infrastructure) directly targeting and penetrating the permeability barriers of adjacent compartmentalized reservoirs. This capability allows them to bring wells from 3,000 B/D to more than 8,000 B/D, up to 10,000 B/D.

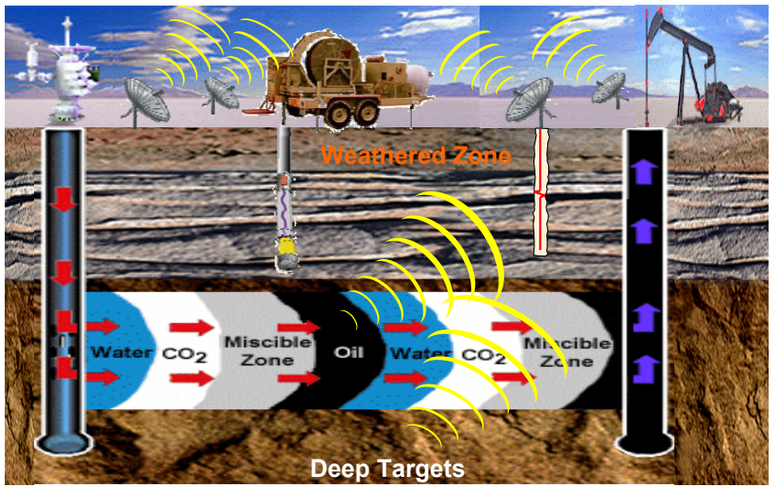


Cost effective reservoir imaging is equally as important as cost effective access (drilling) in the reservoir. With regard to CO2 EOR, cost effective imaging is perhaps more important because it is required first for effective planning and secondly, it is required for continuous monitoring of CO2 movement and identification of previously unnoticed reservoir compartmentalization.



DOE's Microhole Technologies Roadmap meeting was held in Albuquerque, NM, April 29-30, 2003. It was noted by the geophysicists in attendance then that "VSP sees downward very nicely. How nicely, we do not know; it's not been utilized that way before." This potential capability for a new approach to cost effective high resolution imaging, along with the newly established technology of Micro-Electromechanical Machine Systems (MEMS) that results in very small geophones and accelerometers for use in seismic applications, makes possible the concept of "designer seismic". In brief, designer seismic is the program to investigate the potential of achieving a cost effective areal seismic "view" of the subsurface using multiple purpose built high resolution VSP imaging boreholes instead of the typical seismic surface array. The key to the capability is developing an effective low cost deployment system capable of drilling at least 500' below the surface very quickly with minimal environmental footprint. An example of one of the new "micro-geophone" elements in a VSP array is shown on the right in this slide. The entire array can be run to depths greater than 500' by hand, thus eliminating the need for a completion/workover rig to run and retrieve the array. The micro-geophone package in the photo includes an inflation bladder for "locking" the geophone to the wall of the casing. This simple hand deployed system results in very fast, low cost deployment and data acquisition per borehole. This is essential considering many boreholes will be required to achieve the desired areal coverage for operations such as EOR.

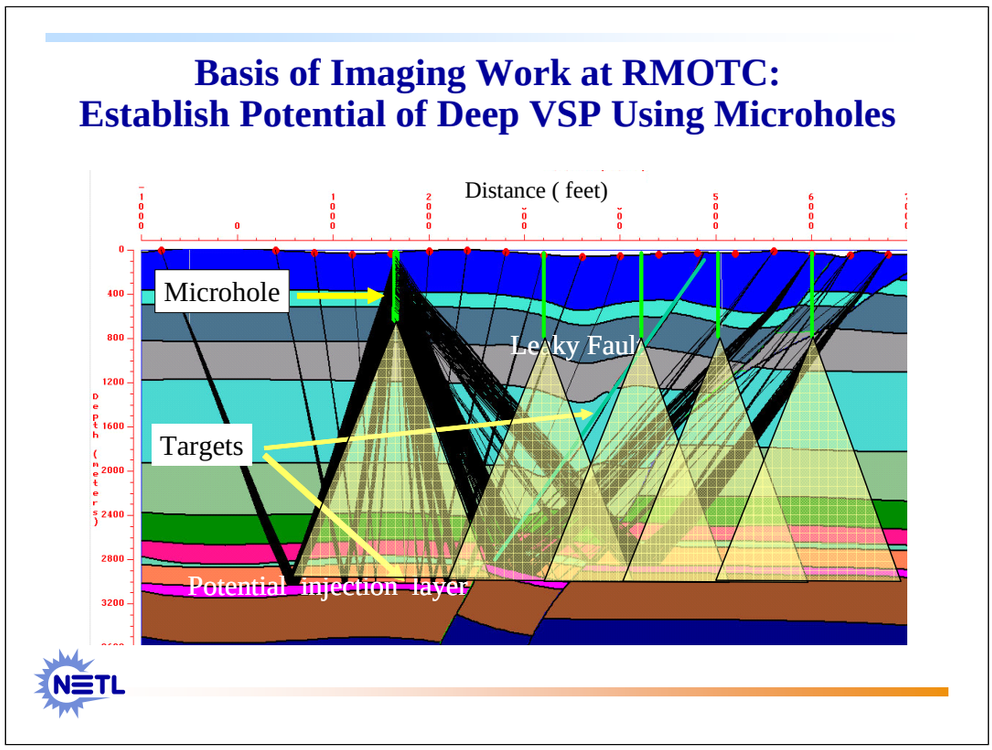
Possible Results of Successful RMOTC MHT Work:
– Improved EOR using "Designer Seismic" with VSP
– Long Term Passive Seismic for Low Impact Exploration



Note: Modified from Kinder Morgan CO_2 LP Company

One of the key advantages of VSP versus conventional seismic arrays is the ability to get below what is termed the "weathered zone". This typically comprises at least the first 300' of overburden where 80% of the seismic signal is lost going from the surface to the target zone; and another 80% of the reflected signal is lost in the return to conventional surface receivers. This total lost in energy results in the high frequency components of the reflected wave essential to high resolution definition more often than not being completely absent at surface receivers. Just getting below the weathered zone could result in an of order magnitude in improved high frequency response.

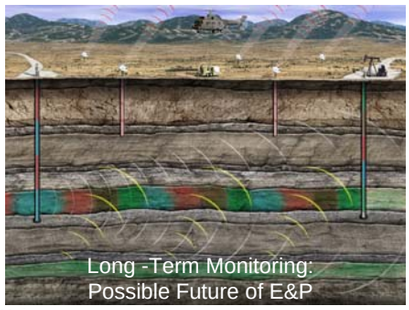
Another goal of "designer seismic" is to investigate the full potential of "purpose built" seismic boreholes. By using plastic and other sound deadening materials for casing (now possible in the shallow boreholes), it might be possible to further develop capabilities currently under investigation in "continuous, real time, passive seismic monitoring". This has the potential to further reduce the cost of imaging by utilizing computer automation to analyze a multitude of natural and undirected manmade sources and provide a continuously updated image of the reservoir for only the cost of monitoring and computing equipment.



This graphic best illustrates the need for overlap of the borehole “coverage” areas to produce the full seismic picture. This might best be thought of as simply a paradigm shift in how to design a high resolution seismic array. Looking down from the shallow borehole results in a high resolution image of a circular area with a diameter of ½ the distance between the borehole and the target. The effect might be likened somewhat to a flashlight.

Status of National Lab "Designer Seismic" Work at RMOTC

- **Microholes and VSP Data Acquisition Completed - October 2004**
- **Phase II - FY05, August**
  - Drill 3-4 new Microholes across fault (LANL)
  - Set Micro-geophone based data acquisition system (LBNL)
  - Acquire Active VSP Seismic HiRes Image (LBNL)
  - Initiate passive seismic investigation (U. of Wyoming)



The first trials for Designer Seismic were initiated at the Rocky Mountain Oilfield Test Center in 2003. The goal of the program was to image a fault not able to be imaged by surface seismic because of significant near surface breciation in the vicinity of a fork where the fault split in two and was not even mapable at surface except outside the area of breciation near the fork. Most recently testing was completed and the data is being processed with anticipation of now being able to image the fault. Conclusions from testing to date are:

Active seismic

Microhole VSP can look up to 5-10 times hole depth

Resolution (due to reduced signal to noise) is up to three time better than "conventional" VSP

Makes seismic surveys are faster and much cheaper

Allows operator to easily customize/change surveys for changing reservoir conditions and varying reservoir conditions across any particular field

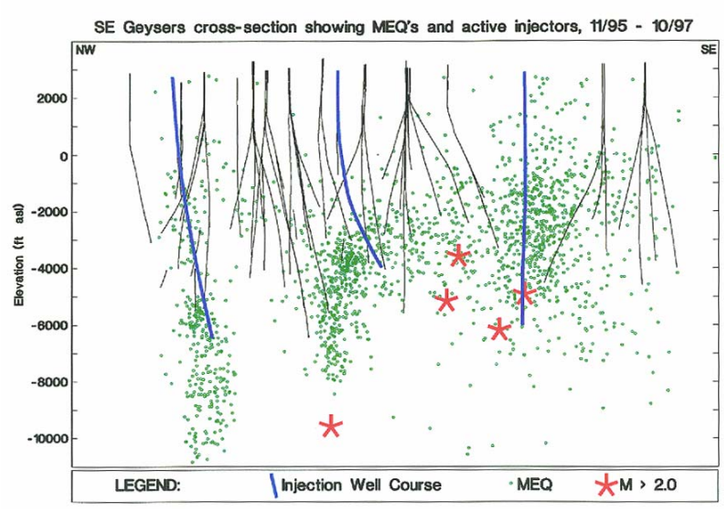
Passive Seismic

Critical information on fracture generation, fluid interactions and fluid paths can be obtained from borehole seismic data

Sensors do not need to be placed at reservoir level

Sensors do need to be placed away from surface and in sufficient azimuthal coverage to eliminate path effects and obtain data for analysis of source mechanisms critical to understanding fracture generation and analysis.

Progression of Game Changing Technologies: VSP Long-Term Monitoring Potential (From Existing LBNL Seismic Network)



(Stark, 1992)

The Designer Seismic program is leveraging funding by taking advantage of Lawrence Berkeley National Lab investigators co-participation in ongoing seismic studies associated with geothermal seismic activity. A key study is currently underway at the Geysers field in California. Re-injection of water from produced steam is now being associated with seismic events with magnitudes greater than 2.0. Existing scientific seismic monitoring boreholes in the area allowed investigators to utilize latest technologies to better study these seismic events. Conclusions to date are:

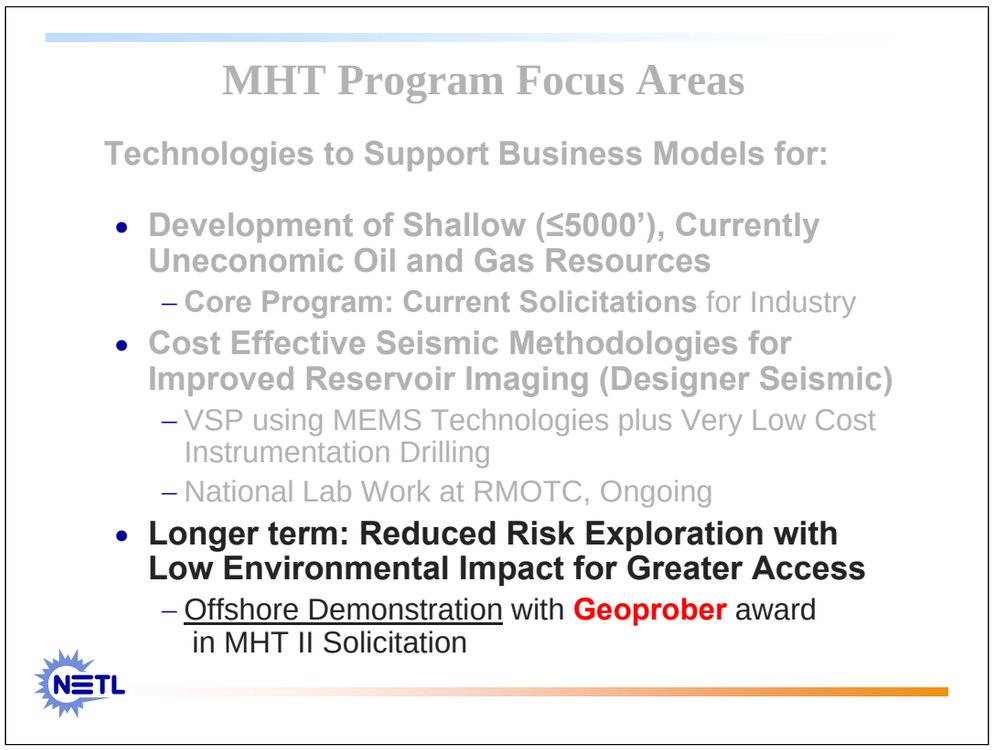
1) Seismic sources can be located via vector analysis from multiple monitoring boreholes to within 1 meter of the event.

2) All conclusions noted in previous slide under “passive seismic”

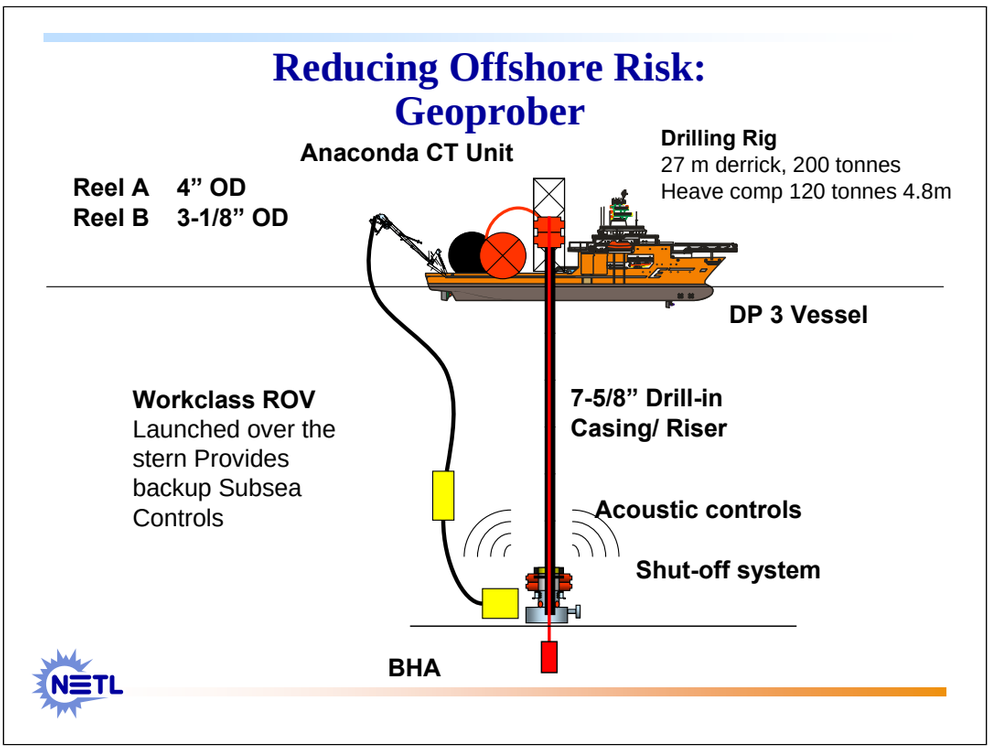
- Critical information on fracture generation, fluid interactions and fluid paths can be obtained from borehole seismic data

- Sensors do not need to be placed at reservoir level

- Sensors do need to be placed away from surface and in sufficient azimuthal coverage to eliminate path effects and obtain data for analysis of source mechanisms critical to understanding fracture generation and analysis.



Application of the previous "cost/risk reduction" concepts being developed in the Microhole Technologies Program are especially applicable to both deepwater offshore and environmentally sensitive areas onshore. The offshore focus is being developed by Geoprober Drilling Ltd.



The Geoprober project is a plan to employ innovative coiled tubing and a smaller work/stimulation vessel (versus full scale drill ship) to drill low-cost, shallow, slim/microhole exploration wells in water depths as great as 10,000 feet at a significantly lower cost than with a conventional drilling system. Cost savings have been projected of as much as 59%. These savings would come from a notable reduction in the size of the drilling equipment and from time savings resulting from a radical rethinking of how to establish the well in the seabed.

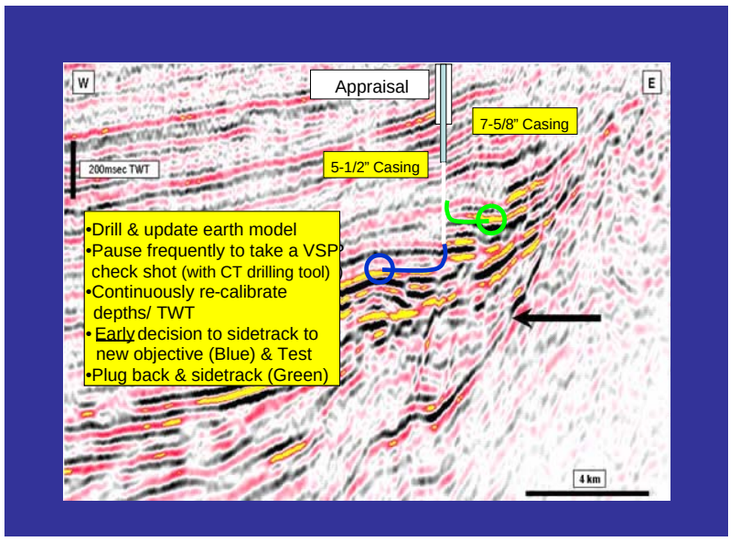
And nowhere are such cost reductions needed more than in the U.S. Gulf of Mexico, where only about 10% of deepwater leases are drilled owing to the high cost and limited availability of suitable deepwater drilling rigs. Consequently, only the largest prospects with the greatest chance of success in the deepwater gulf are getting drilled. Once such a low-cost, innovative drilling system is widely available, more independent operators would be willing to venture into the gulf’s deep water as well, shedding their prior reluctance instilled by the province’s high costs. And a much broader portfolio of deepwater prospects would become economically attractive to drill, thereby bolstering U.S. energy security.

The aim is to confirm the capability to drill low-cost, shallow slim/microhole exploration wells in water depths ranging up to 10,000 feet.

Cost savings would come by using a smaller drilling vessel and by eliminating the need to deploy and retrieve a large riser.

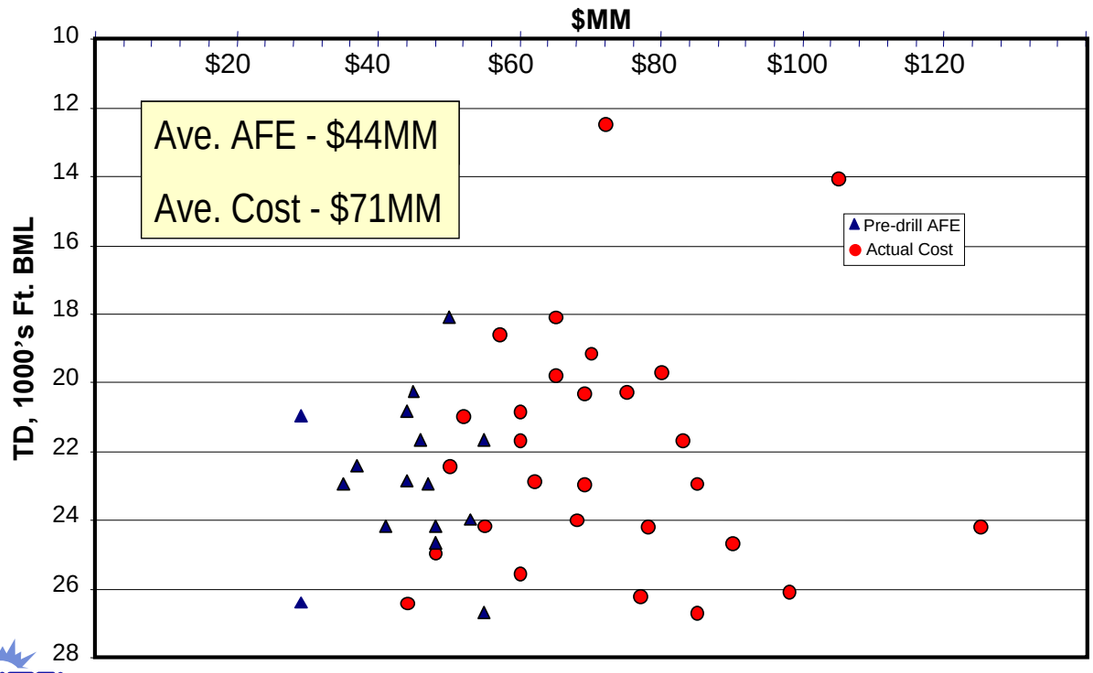
Geoprober Drilling Inc., Houston, TX, has developed a new type of seabed support system that incorporates a subsea shutoff system and surface BOP. This system enables slim “finder wells” to be established in deep water with drilled-in casing.

Fast Sidetracks to Check Geological Model



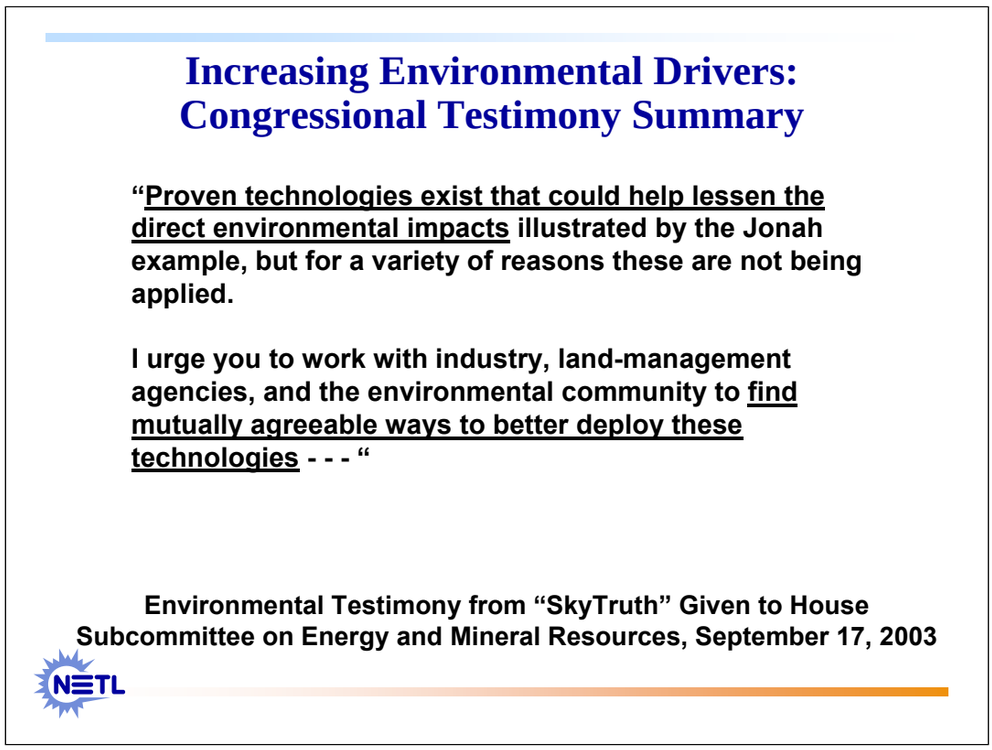
Several key capabilities essential to reducing exploration risk that are expected to be provided cost effectively by Geoprober are noted in this slide.

Need for Offshore Risk Reduction:
Ultra-Deep GOM Well Cost ~60% More Than AFE!



ConocoPhillips DEA Presentation, 1st Quarter 2004

The importance of reducing Deepwater risk is best shown in this slide. It was developed from public information during the time when deepwater drillships leased for approximately $300K/day. That cost is now exceeding $400K/day. This level of cost overrun cannot be continuously absorbed by operators if the deepwater GOM is to be fully developed.



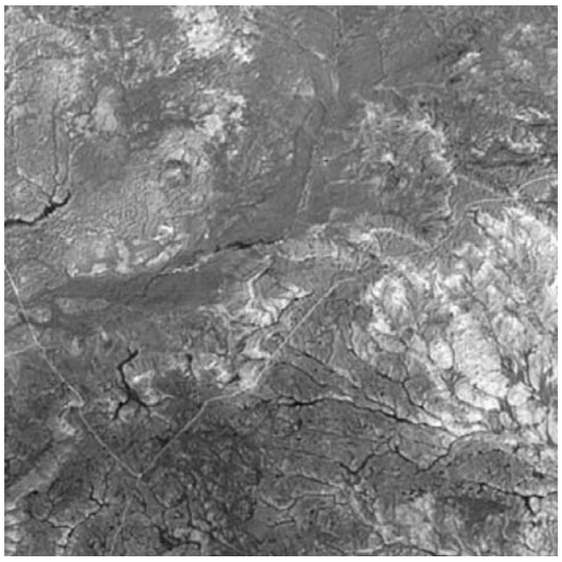
Today there is increased and increasing focus on minimizing environmental impact across the board for E&P. This next series of slides exemplifies that environmental pressure. The environmental group, Sky Truth, testified during a hearing by the House Subcommittee on Energy and Mineral Resources in September, 2003. It was very significant because, instead of insisting on no drilling, the group simply asked that Government work with Industry and the Environmental Community to find mutually agreeable ways to better deploy existing technologies minimize environmental impact.

Rocky Mountain E&P
Technology Currently Used

State-of-Art Rigs - - - 50+ Year Old Environmental Footprint

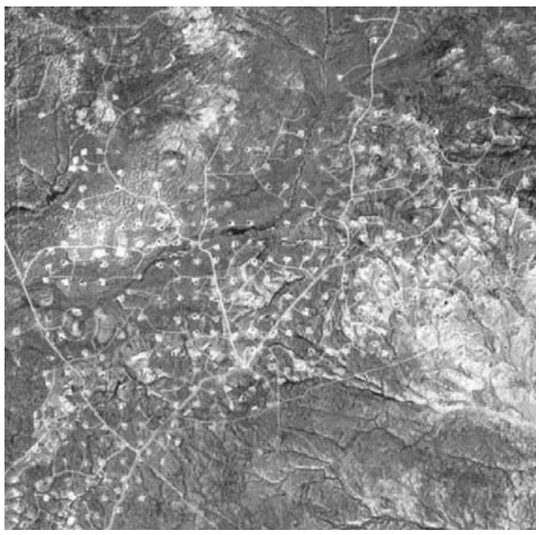
For example, Sky Truth noted this example of rigs being used to develop the Jonah field in Southwest Wyoming. While the rig is likely “state-of-art” with respect to drilling capability and communication with the home office, the drilling pad/location has not changed in over 50 years. The location is very large and causes an environmental impact to the land that some environmentalists argue will not be able to be reclaimed for a very long time, if ever.

Jonah Field: 1986, Prior to Development



For comparison, this photo was taken prior to any field development.

Jonah Field: 2002, 40 Acre Spacing

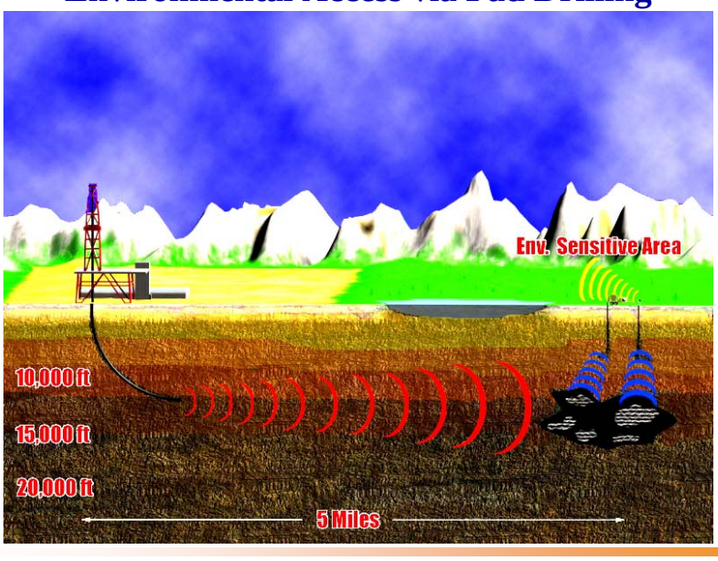


Currently
More than
400 Wells

Application for 20 Acre Spacing > 850 New Wells

In this photo, the same road intersection can be seen with not only additional roads build but more than 400 well locations. This was offered to emphasize what the impact of the additional 850 wells would likely be if the 20 acre spacing request was granted.

Future MHT Applications?
Enabling Extended Reach Drilling and Environmental Access via Pad Drilling



NETL

One of the potential applications of “designer seismic” would be to provide high resolution imaging of subsurface targets using remote data acquisition systems that cause minimal environmental impact. If geologic risk can be minimized for exploration, it might be possible to make pad drilling cost effective. Pad drilling is already being used in Canada very successfully.

Economically Approaching Zero Site / Environmental Impact

"Onshore Mobile Platform: A Modular Platform for Drilling and Production Operations in Remote and Environmentally Sensitive Areas"" SPE Paper #87140

Slide Courtesy of Anadarko

An extension of pad drilling might also be utilization of onshore, elevated platforms such as this one utilized by Anadarko to minimize environmental impact of recent Arctic operations. The good relations created with regulatory agencies by Anadarko showing what is possible cannot be overestimated.

Tomorrow's Potential Benefits from Pad / Modular Drilling

- Reduced E&P Risk
- Reduced Development Cost
- Reduced Environmental Risk: Reduce Shutdown Periods

- Increased Efficiency in Production Operations
- Improved Access to Culturally and Environmentally Sensitive Areas Through Better Technology

In summary, many technologies from DOE's Microhole Technologies Program are being made commercial that will both change current R&D paradigms to make E&P more cost effective and environmentally friendly

More Information / Questions

Microhole Integration Meetings:
Be Watching PTTC – http:www.pttc.org
First Meeting: August 17, 2005
Next Meeting: November 16, 2005

www.netl.doe.gov/scngo/index.html

www.fossil.energy.gov/programs_oilgas.html